Bell Ringer: Determining the Relationship Between Displacement, Velocity, and Acceleration – ID: 13308

Time required
15 minutes

Topic: Kinematics

- *Construct and interpret graphs of displacement, velocity, and acceleration versus time.*
- *Relate the slope of a displacement function to velocity and the slope of a velocity function to acceleration.*

Activity Overview

In this activity, students will determine the slope of a displacement versus time function at various times. They will then plot the data to obtain the velocity versus time function. They will repeat this process to obtain the acceleration versus time function. Students will analyze the three functions to observe the relationship between displacement, velocity, and acceleration.

Materials

To complete this activity, each student or student group will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank paper*

TI-Nspire Applications

Graphs & Geometry, Notes, Lists & Spreadsheet

Teacher Preparation

Before carrying out this activity, review with students the kinematic equations for displacement and velocity as a function of time. Make sure that students understand what the variables in each equation represent.

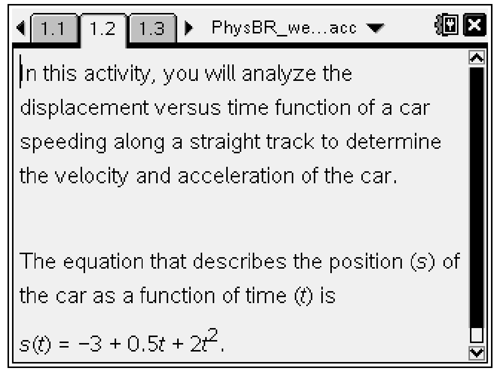
- *The screenshots on pages 2–5 demonstrate expected student results. Refer to the screenshots on pages 6 and 7 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains data analysis and answers to the questions.*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter "13308" in the search box.***
- *This activity is related to activity 8549: Takeoff of an Airplane. If you wish, you may extend this bell ringer activity with the longer activity. You can download the files for activity 8549 at education.ti.com/exchange.*

Classroom Management

- *This activity is designed to be* ***student-centered****, with the students working cooperatively. However, you will need to guide students through the steps of the activity.*
- *If you wish, you may modify this document for use as a student worksheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*
- *If students do not have sufficient time to complete the questions, they may also be completed as homework.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

Students will obtain the slope of a displacement versus time equation at various points. They will then plot the slope as a function of time, fit a line to the data, and determine an equation for the line. They will also determine the slope of this line. Finally, students will identify the relationship between displacement, velocity, and acceleration.

Step 1: Students should open the file **PhysBR_week02_dis_vel_acc.tns** and read the first two pages. (Students can press ctrl ▶ and ctrl ◀ to move between pages in the .tns file.)



Step 2: Students should move to page 1.3 and answer question 1. Students can type their answers into the *Notes* application on page 1.3, or they can write their answers on a sheet of blank paper.

Q1. Analyze the displacement versus time equation to determine the car's initial position (s_0), initial velocity (v_0), and acceleration (a). Assume that distance is measured in meters and time is measured in seconds.

A. *For motion in one dimension, the following general equation applies:*

$$s(t) = s_0 + v_0 t + \frac{1}{2}at^2$$

A comparison of this general equation with the equation given for the car's motion yields the following:

$s_0 = -3$ *m;* $v_0 = 0.5$ *m/s;* $a = (2)(2) = 4$ *m/s*^{2}

Step 3: Next, students should move to page 1.4 and answer question 2.

Q2. Recall the kinematic equation for velocity. Using the values from question 1, write an equation for the velocity (*v*) of the car as a function of time.

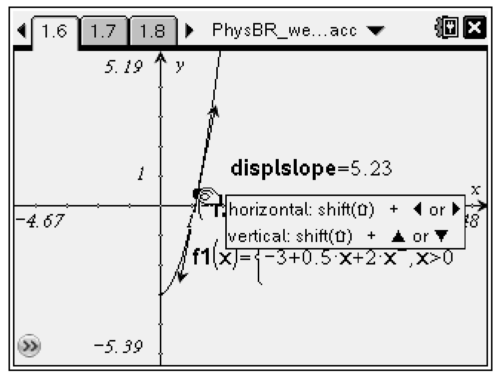
A. *For motion in one dimension, the following general equation applies:*

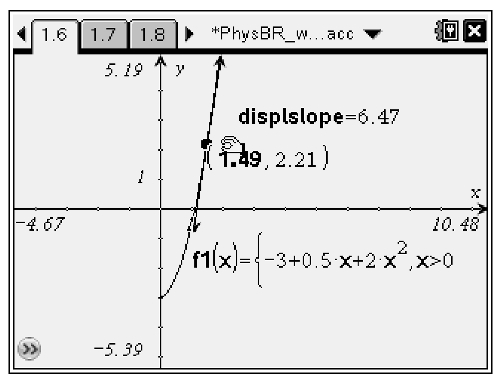
$v(t) = v_0 + at$

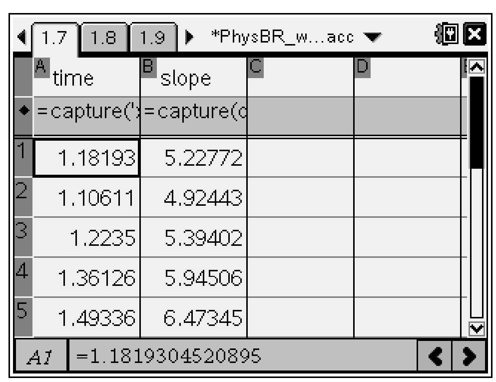
Using the values v_0 = 0.5 m/s and *a* = 4 m/s^2, *the velocity equation can be written as*

$v(t) = 0.5 + 4t$.

Step 4: Next, students should read the text on page 1.5 and then move to page 1.6, which contains a *Graphs & Geometry* application. The displacement versus time equation is plotted, along with a tangent line. (Note that the *x*-variable on this graph is time.) The coordinates of the tangent point and the slope of the tangent line are also displayed on the screen. Students should drag the tangent line to various points along the curve. (To drag the tangent line, they should use the NavPad to move the cursor over the intersection point of the curve and the line. The cursor will turn into an open hand. Students should press and hold (click) until the hand closes, indicating that they have "grabbed" the point. They can then use the NavPad to drag the point along the line.) As students move the point along the curve, the device will use automatic data capture to store the *x*-coordinate of the point and the slope of the line on the *Lists & Spreadsheet* application on page 1.7.



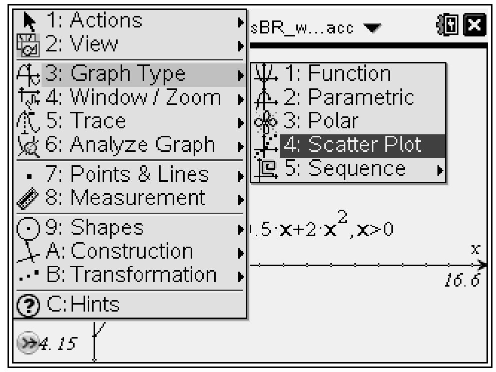


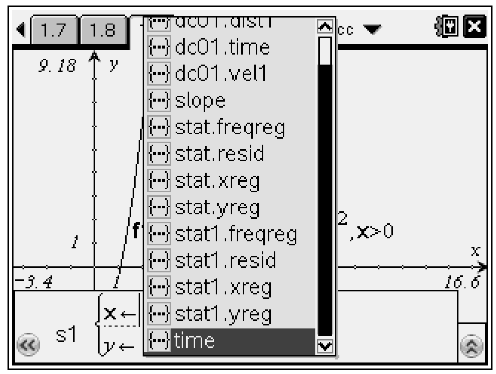


	A time	B slope	C	D
◆	=capture('	=capture(c		
1	1.18193	5.22772		
2	1.10611	4.92443		
3	1.2235	5.39402		
4	1.36126	5.94506		
5	1.49336	6.47345		

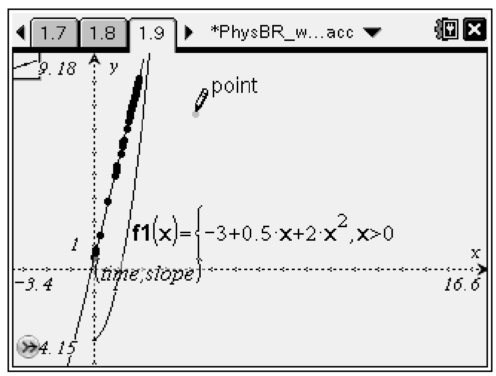
A1 =1.1819304520895

Step 5: Next, students should read the instructions on page 1.8 and then graph the time and slope data on page 1.9. First, students should change the graph to a **Scatter Plot** graph (**Menu > Graph Type > Scatter Plot**). At the bottom of the window, they should select **time** as the *x*-variable and **slope** as the *y*-variable. (Students can press (var) to open the drop down menu for each variable. They should press (click) to select a variable and (tab) to move between the *x* and *y* variables. After they have selected the appropriate variables, students should press (enter) to graph the data points.)

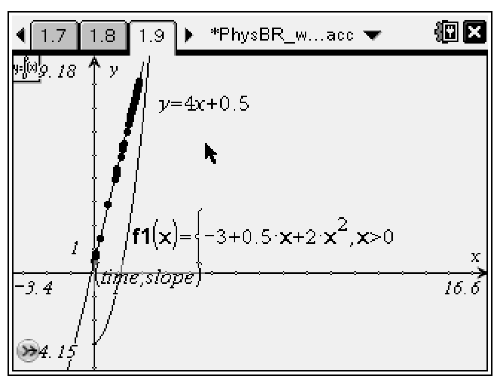




Step 6: Next, students should use the **Line** tool (**Menu > Points & Lines > Line**) to draw a line connecting the data points. To use the **Line** tool, students should click on two of the data points shown to draw a line connecting them. They should then press (esc) to exit the tool.



Step 7: Next, students should use the **Coordinates and Equations** tool (**Menu > Actions > Coordinates and Equations**) to determine the equation of the fitted line. To use the **Coordinates and Equations** tool, students should click on the fitted line (not any of the points). The equation for the line should be displayed onscreen. Students can then click anywhere on the screen to place the equation there. They should press (esc) to exit the tool. Next, students should answer questions 3–7.



Q3. How does the equation of the line you determined on page 1.9 compare to the velocity equation that you determined on page 1.4? Why do you think this is the case? (Hint: Think about the equation for the slope of a line and the definition of velocity.)

A. *Students should note that the equation of the line on page 1.9 is the same as the equation for velocity. This can be explained by examining the equations for the slope of a line and velocity. The equation for the slope of a line between points (t_1, s_1) and (t_2, s_2) is given by $slope = \frac{s_2 - s_1}{t_2 - t_1}$. The definition of velocity is $v = \frac{\Delta s}{\Delta t}$. It follows that the slope of a line tangent to a point on the displacement versus time curve is equal to the velocity at that time.*

Q4. What is the slope of the best-fit line you plotted on page 1.9?

A. *Students should be able to determine the slope of the line by examining the equation for the line. The slope of the line should be 4.*

Q5. How does slope of the best-fit line compare to the acceleration of the car determined from its position versus time equation? Why is this the case?

A. *Students should note that the slope of the fitted line is equal to the acceleration of the car determined on page 1.3. The equation for the slope of a line between points (t_1, v_1) and (t_2, v_2) is given by $slope = \frac{v_2 - v_1}{t_2 - t_1}$. The definition of acceleration is $a = \frac{\Delta v}{\Delta t}$. It follows that the slope of a line tangent to a point on the velocity versus time curve is equal to the acceleration at that time.*

Q6. What can you state about the relationship between the displacement and the velocity of the car? What can you state about the relationship between the velocity and the acceleration of the car?

A. *The velocity of the car can be determined from the slope of the displacement versus time graph. The acceleration of the car can be determined from the slope of the velocity versus time graph.*

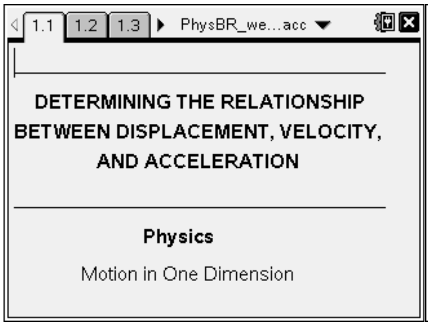
Q7. The slope of the best-fit line on page 1.9 is constant. What does this indicate about the acceleration of the car?

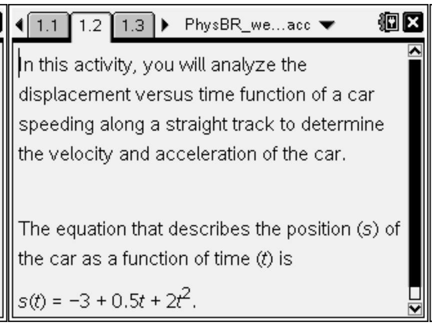
A. *This indicates that the acceleration of the car is constant.*

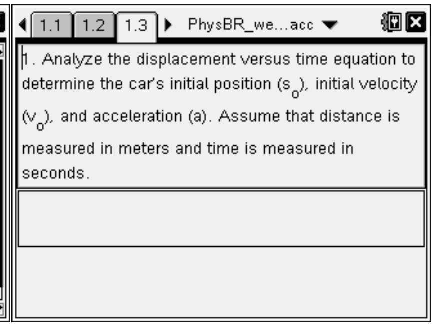
Suggestions for Extension Activities: If you wish, you may have students repeat the investigation using a variety of position versus time functions. To do this, have students change the equation for the displacement versus time graph on page 1.6. (They can change the equation by pressing ctrl G to show the function line and then using the NavPad to scroll to function **f1**.) They can then follow the same procedures detailed in this activity to determine the corresponding velocity and acceleration functions.

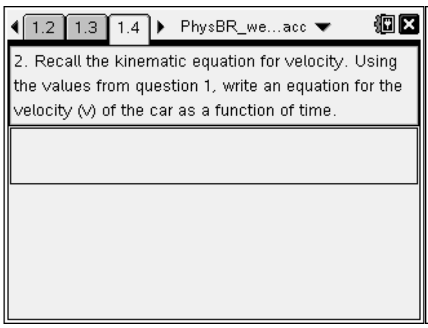
Bell Ringer: Determining the Relationship between Displacement, Velocity, and Acceleration – ID: 13308

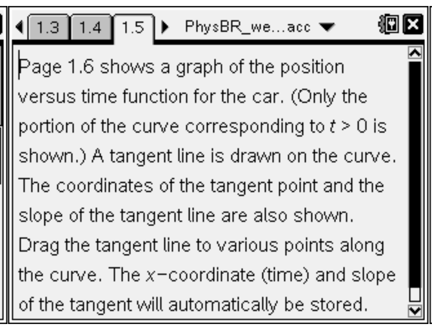
(Student)TI-Nspire File: *PhysBR_week01_dis_vel_acc.tns*

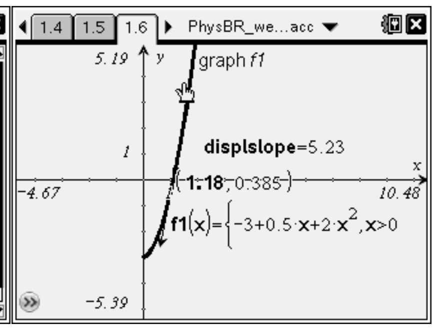


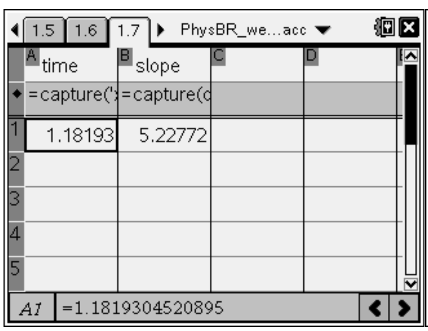


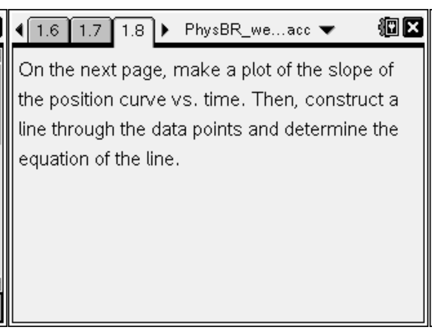


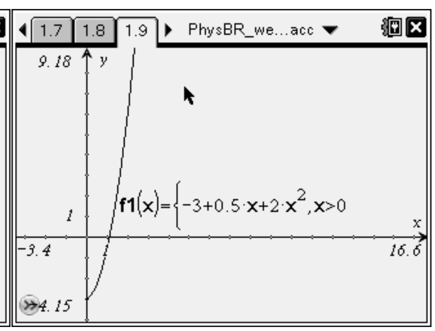


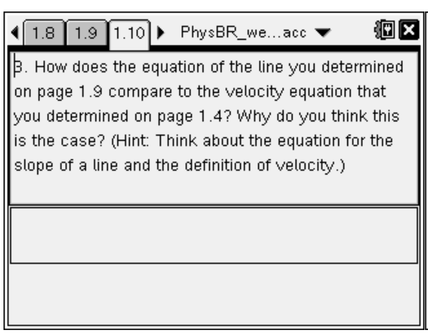


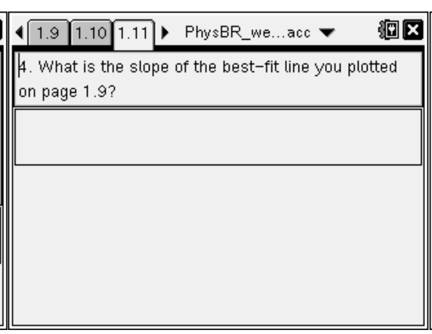


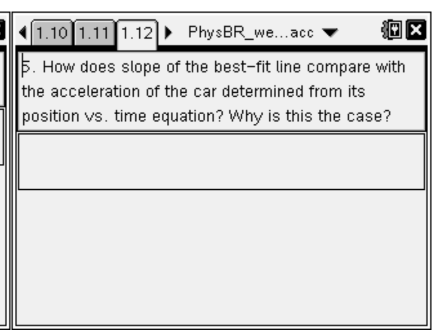


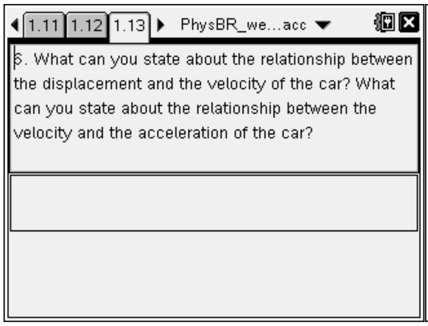


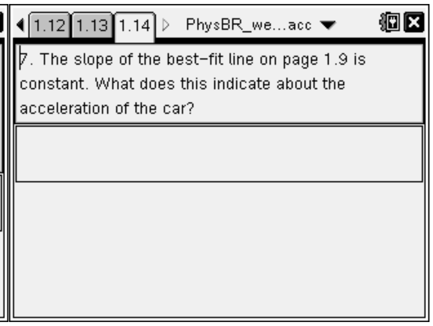









1.11 1.12 1.13 PhysBR_we...acc
6. What can you state about the relationship between the displacement and the velocity of the car? What can you state about the relationship between the velocity and the acceleration of the car?


1.12 1.13 1.14 PhysBR_we...acc
7. The slope of the best-fit line on page 1.9 is constant. What does this indicate about the acceleration of the car?